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Rehabilitation for scapholunate injury: Application of scientific and clinical evidence to practice

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ABSTRACT

In this article, the development of a rehabilitation approach is describe using scapholunate injury as a model. We demonstrate how scientific and clinical evidence is applied to a treatment paradigm and modified based on emerging evidence. Role of the scapholunate interosseous ligament within the pathomechanics of the carpus, along with the progression of pathology, and specific rehabilitation algorithms tailored to the stage of injury. We review the recent and current evidence on the kinematics of wrist motion during functional activity, role of the muscles in providing dynamic stability of the carpus, and basic science of proprioception. Key relevant findings in each of these inter-related areas are highlighted to demonstrate how together they form the basis for current wrist rehabilitation. Finally, we make recommendations for future research to further test the efficacy of these approaches in improving functional outcomes.

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Introduction

The development of a rehabilitation approach for a specific injury follows an iterative process. First, the impairment and mechanism of injury must be clearly identified, defined, and understood. Next, treatment approaches are developed that are based on a thorough understanding of anatomy, biomechanics, pathomechanics of the particular injury, and prior scientific and clinical studies. Finally, these interventions are tested for efficacy in a clinical setting with the ultimate goal of improving function. This final step is critical to confirm the value and efficacy of an intervention in achieving its desired outcome. This article demonstrates how scientific and clinical evidence is applied to a treatment paradigm and modified based on emerging evidence. The role of the scapholunate interosseous ligament (SLIL) is described within the context of carpal pathomechanics, followed by an explanation of the progression of pathology. The article reviews the recent and current evidence on the kinematics of wrist motion during functional activity, role of the muscles in providing dynamic stability of the carpus, and basic science of proprioception. In each section, the key relevant findings are highlighted with suggestions and descriptions for specific rehabilitation applications to demonstrate how these inter-related areas form the basis for current wrist rehabilitation. Finally, recommendations for future research are made to further test the efficacy of these approaches in improving functional outcomes.

Overview of scapholunate injury: Current understanding

Carpal anatomy and biomechanics

An understanding of wrist biomechanics is required to appreciate the role of the scapholunate (SL) joint in overall carpal function. The wrist joint comprises complex articulations between the 5 metacarpals, the 8 carpal bones, and the forearm. The carpus has been traditionally conceptualized as a dual linkage system of either rows or columns.[1] The bones in the distal row (trapezium, trapezoid, capitate, and hamate) are bound tightly together through strong intercarpal ligaments that allow for minimal motion between the bones. The bones in the proximal row (scaphoid, lunate, and triquetrum) have been described as an intercalated segment due to their synchronized motion despite the lack of direct tendon insertion.[1-3] Carpal motion is relative to wrist motion; therefore, the scaphoid, lunate, and triquetrum rotate as a unit in flexion or extension depending on the direction of wrist movement. With wrist flexion and radial deviation, the proximal carpal row flexes, and with ulnar deviation and extension, the proximal carpal bones extend.[4] Carpal kinematics depends on

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the mechanical proprioceptive signals from the surrounding articulations that are transmitted via a complex ligamentous system.[5] When this system is disrupted, instability ensues through changes in individual carpal bone motion and load transmission, which leads to pain and loss of function. SL joint stability depends on the contribution of 4 factors: intact articular surfaces, ligamentous congruity, muscle contractions that provide joint compressive forces, and neuromuscular/proprioceptive control of the joints.[1,6,7]

The role of the SLIL in carpal function

The SLIL is the primary stabilizer of the SL joint. It is a c-shaped ligament (Fig. 1) that attaches along the dorsal, proximal, and volar margins of the articulating surfaces. It has been divided anatomically and histologically into 3 subdivisions: dorsal, membranous, and volar.[8,9] The dorsal component is the strongest and most critical to SL joint stability and acts as a primary restraint to joint separation in wrist flexion and extension. The considerably weaker volar ligament is important in controlling rotational stability. The intermediate membranous portion is of little consequence mechanically. The SLIL is also richly innervated and provides critical proprioceptive input for dynamic wrist stability.[10,11] Additional stability is provided to the SL joint through secondary stabilizers, in particular the scaphotrapezialtrapezoidal, radioscaphocapitate, and dorsal intercarpal ligaments. In the intact wrist, the posture of the lunate is controlled by the flexion and extension moments applied through the scaphoid and triquetrum, respectively.[12] SLIL injury disrupts this balance and sets off a chain of events beginning with changes in force transmission and kinematics across the SL joint. Complete disruption of the SLIL and subsequent loss of distal support at the scaphotrapezialtrapezoidal joint leads to pathologic extension of the lunate, otherwise known as dorsal intercalated segment instability.[13] Over time, untreated SLIL disruption leads to progressive scapholunate advanced collapse arthritis with accompanying pain and impaired function. Surgery to address the spectrum of SL and radiocarpal injury includes a range of procedures that effectively decrease pain and prevent further degenerative changes. Acutely, SLIL disruption may be treated with a primary repair of the ligament. These injuries, however, often are undiagnosed and progress to require salvage procedures such as a proximal row carpectomy (PRC) and a range of intercarpal fusions. The degree to which carpal kinematics can effectively be restored depends largely on the timing of the intervention and degree of degenerative change. At all times, the goal of surgery and rehabilitation is to maintain optimal mechanics, protect stability, and restore function and mobility.

Wrist kinematics, dynamic stability, and proprioception: Implications for SLIL rehabilitation

Functional kinematics of the wrist

A fundamental understanding of carpal kinematics is essential and integral to early rehabilitation of SL reconstruction so that motion can be minimized at the injured or repaired sites and directed along a safe plane of movement. A recent review of functional wrist kinematics by Rainbow et al[14] describes the historical progression of measurement techniques for carpal kinematics with related findings. The following section highlights and expands on those studies that have direct clinical relevance for the development of rehabilitation interventions.

Coupled wrist motion

Dart-thrower's motion. An important and relevant premise is that functional wrist motion occurs along coupled paths of motion and not in pure planes of flexion/extension and radial/ulnar deviation. Coupled wrist motion, defined as a composite motion of flexion/extension and radial/ulnar deviation, has been studied *in vivo* and *in vitro* in terms of both macro (global wrist) and micro (individual carpal) kinematics. Examples of coupled wrist motion include dart-thrower's motion (DTM) and circumduction, and are explained in detail below. DTM was first described by Palmer et al,[15] has been studied extensively.[16-22]

Motion of scaphoid and lunate in DTM plane. Early 3-dimensional studies of carpal bone motion in intact wrists

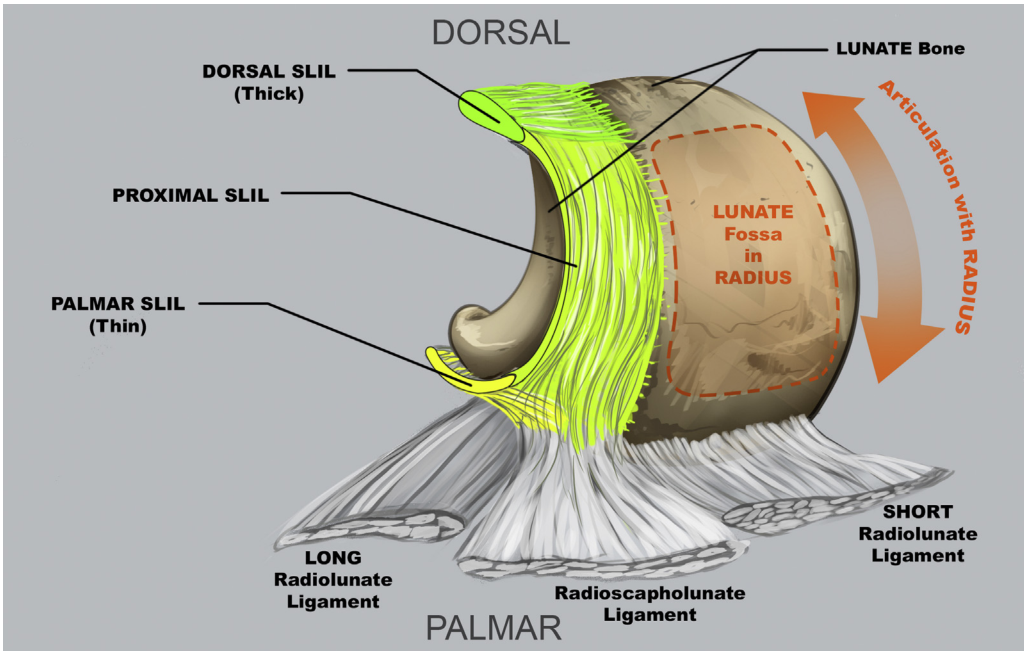

Fig. 1. The scapholunate interosseous ligament (SLIL) viewed from the proximal/radial side with the scaphoid removed.

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